

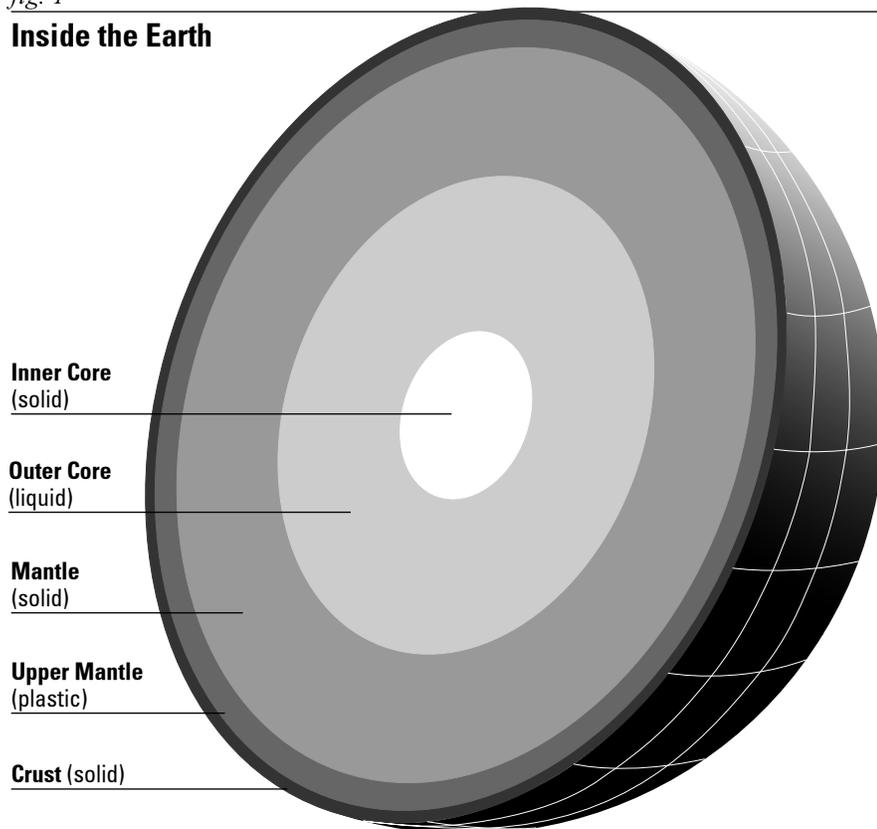
WINDOWS INTO THE EARTH

VOLCANOES!

LESSON 1

fig. 1

Inside the Earth



Magma is generated in the Earth's lithosphere, which is made up of the crust and upper mantle.

Until the spring of 1980, most people thought of Mount St. Helens as a serene, snow-capped mountain and not as a lethal **volcano**. The mountain had given little evidence that it posed a hazard for more than a century—a long time in human terms but a blink of an eye in terms of the mountain's 50,000-year geologic history. A series of earthquakes that began in mid-March of 1980 sounded the alarm that Mount St. Helens was awakening from its sleep. In other words, Mount St. Helens, which had been

dormant, became **active** and likely to erupt. Its catastrophic eruption 2 months later was a reminder that a fiery world lies beneath the Earth's surface.

Why Volcanoes Occur

The roots of Mount St. Helens's are 110 to 330 kilometers (70 to 200 miles) below the Earth's surface. Here in the Earth's **mantle** (fig. 1) temperatures are hot enough to melt rock and form a thick, flowing substance called **magma**. Lighter than the solid rock that surrounds it,

magma is buoyant much like a cork in water; being buoyant, it rises.

As the magma rises, some of it collects in large reservoirs, or magma chambers (poster fig. 1) that fuel volcanoes. As the rising magma nears the Earth's surface, pressure decreases, which causes the gases in the magma to expand. This expansion propels the magma through openings in the Earth's surface: a volcanic eruption occurs. Once magma is erupted, it is called **lava**.

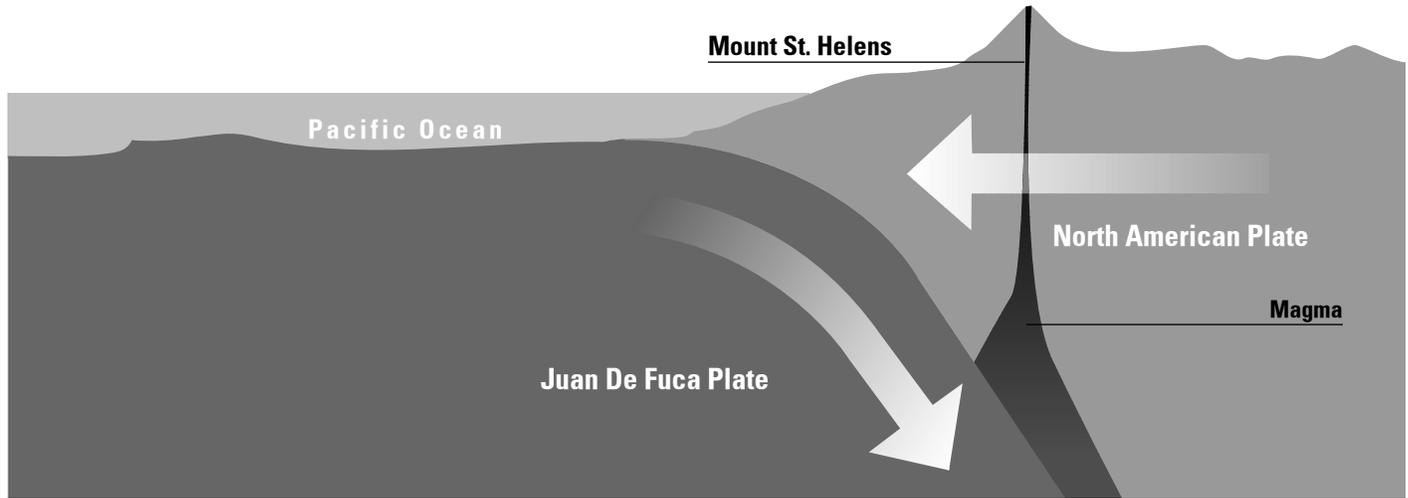
Where Volcanoes Occur

Volcanic eruptions occur only in certain places and do not occur randomly. That's because the Earth's outermost shell—the **lithosphere**—is broken into a series of slabs known as **lithospheric** or **tectonic plates**. These plates are rigid, but they float on the hotter, softer layer in the Earth's mantle. (poster fig. 2) As the plates move about, they spread apart, collide, or slide past each other. Volcanoes occur most frequently at plate boundaries.

Some volcanoes, like those that form the Hawaiian Islands, occur in the interior of plates at areas called **hot spots**. (poster fig. 2) Although most of the active volcanoes we see on land occur where plates collide, the greatest number of the Earth's volcanoes are hidden from view, occurring on the ocean floor along **spreading ridges**.

Mount St. Helens is typical of more than 80 percent of the volcanoes that have formed on land. Known as **subduction zone** volcanoes, they occur along the edges of continents where one plate

Inside the Earth



About 240 kilometers (150 miles) west of the northwest coast of the United States, the Juan de Fuca Plate plunges beneath the North American Plate. Mount St. Helens is among the volcanoes that have formed as a result.

dives, or subducts, beneath a second plate. (fig. 2). When the subducting plate reaches about 100 kilometers (60 miles) into the Earth's hot mantle, it triggers partial melting of the overlying plate and forms new magma. Some of the magma rises and erupts as volcanoes.

Why Some Volcanoes Erupt

Some volcanoes, like Mount St. Helens, tend to be explosive when they erupt, whereas others, like Hawaii's Kilauea, tend to be effusive (loosely flowing) and nonexplosive. How explosive an eruption is depends on the magma's chemical composition and gas content, which in turn affect the magma's stickiness, or *viscosity*.

All magma contains gases that escape as the magma travels to the Earth's surface. If magma is fluid (as is Kilauea's), gases can escape relatively rapidly. As a result, lava flows instead of exploding during an eruption. If magma is viscous

(as is Mount St. Helens), the gases cannot escape easily; pressure builds inside the magma until the gases sometimes escape violently.

In an explosive eruption, the sudden expansion of gases blasts magma into airborne fragments called *tephra*, which can range in size from fine particles of ash to giant boulders. After the initial explosive phase of the eruption, however, quieter lava flows can follow. In both explosive and nonexplosive (effusive) eruptions, volcanic gases, including water vapor, are released into the atmosphere.

Three Types of Volcanoes

Repeated volcanic eruptions build volcanic mountains of three basic types, or shapes, depending on the nature of the materials deposited by the eruption.

Shield volcanoes (poster fig. 5), such as Kilauea, form by effusive eruptions of **fluid lava**. Lava flow upon lava flow slowly builds a broad, gently sloping vol-

canic shape that resembles a warrior's shield.

Stratovolcanoes (poster fig. 4), such as Mount St. Helens, build from both explosive and effusive eruptions. **Layers of tephra** alternating with **layers of viscous lava** flows create steep-sided, often symmetrical cones that we think of as the classic volcano shape. In his log of the Lewis and Clark Expedition, William Clark wrote: "Mount St. Helens is perhaps the greatest pinnacle in America."

The smallest volcanoes, **cinder cones** (poster fig. 3), such as Sunset Crater in Arizona, form primarily from explosive eruptions of lava. Blown violently into the air, the erupting **lava breaks apart into fragments called cinders**. The fallen cinders accumulate into a cone around the volcano's central vent. Cinder cones can form on the flanks of shield and stratovolcanoes.

Activity 1 How Volcanoes Grow

45-minute work session
45-minute demonstration
and discussion

In small groups, students **build models** of the three major types of volcanoes and see how a volcano's shape is related to the type of material it erupts. As a class, they **observe a demonstration** that simulates the nature of two volcanic materials: lava and tephra. The lesson concludes with a **discussion** of how a volcano's shape is related to the nature of the material it erupts.

Key teaching points

1. A volcano is a circular or linear opening in the Earth's surface through which lava, rock fragments, *ash*, *aerosols*, and gases erupt.
2. A volcano is also the landform, often a mountain, built from repeated eruptions.
3. Some eruptions are explosive, some are effusive (loosely flowing) and nonexplosive, and some are both explosive and effusive.
4. There are three major types, or shapes, of volcanoes: (a) stratovolcano, (b) shield volcano; and (c) cinder cone.

Materials

Work Session

1. Master Sheets 1.1, 1.2, and 1.3
2. Colored marking pens (optional)
3. Three 8 1/2" x 11" transparencies for overhead projection
4. Play-doh® in several colors
5. Construction paper or cardboard, three pieces for each group of four students
6. Pencils

Demonstration

1. Three pie plates
2. Three 1-cup measuring cups
3. Cat litter
4. Chilled molasses

Procedures

1. Explain that the photograph on *side 1 of the poster* was taken during the 1980 eruption of Mount St. Helens, a volcano located in the western United States.

2. Introduce the concept that a volcano is both an opening in the Earth's surface through which magma erupts and a landform.

3. Discuss the types of materials that can be erupted: lava, tephra, cinders.

4. Discuss the different styles of eruption: explosive and nonexplosive.

5. At this point, **do not** name the three major volcanic shapes.

6. Divide the class into groups of four students each. Distribute to each group:
 - Master Sheets 1.1, 1.2, and 1.3
 - Three pieces of cardboard or construction paper
 - Play-doh®

7. Using the Master Sheets as guides, each group of students creates a two-dimensional relief model for each of the three types of volcanoes. Master Sheet 1.1 is a **stratovolcano**, Master Sheet 1.2 is a **cinder cone**, and Master Sheet 1.3 is a **shield volcano**.

8. Ask each group of students to list the similarities and differences among the shapes and composition of the three types. (The shield is broad; the stratovolcano has steep sides; the cinder cone is the smallest; and the shield has only layers of lava.)

Discussion

1. On a chalkboard, compile a class list of similarities and differences for each of the three types.

2. Brainstorm why the volcanoes are different. For example, lava is runny like molasses so it spreads out.

Demonstration

1. Do the following demonstration to simulate the nature of lava and the nature of tephra. In one pie plate, slowly pour 1 cup of cat litter (tephra). In a second pie plate, slowly pour 1 cup of chilled molasses (lava).

2. Discuss how the nature of the material influenced the shape of the material built. Discuss what shape you would

expect to get if you alternated a layer of cat litter with a layer of molasses. In the third pie plate, layer molasses and cat litter.

3. Compare the results of your demonstration with the shapes of the three types of volcanoes (*poster fig. 3–5*). Ask student to “type” each of their models.

4. Show students *side 1 of the poster*. What type of volcano is Mount St. Helens? (stratovolcano) What type of eruptions does it have? (explosive) What type of material is in the cloud rising above it? (tephra)

Activity 2 Ring of Fire

30 minutes

Students locate some of the 1,500 active volcanoes on a world map. Then by comparing their maps with a map of the world's tectonic plates, they discover that volcanoes occur because of the dynamic nature of the Earth's lithosphere—the crust and upper mantle.

Key teaching points

1. Volcanoes are windows into how the Earth works. They occur because the Earth's rigid outer shell, the crust and upper mantle, is broken into a mosaic of plates that are in constant motion.
2. Most volcanoes occur along the boundaries of the Earth's tectonic plates.
3. More than half of the volcanoes that are exposed on land form a chain along the converging plates that encircle the Pacific Ocean. This chain is called the "Ring of Fire."
4. Mount St. Helens is located in the "Ring of Fire."

Materials

1. A photocopy of Activity Sheets 1.2a and 1.2b for each student
2. Master Sheets 1.4 and 1.5
3. Two 8 1/2" x 11" transparencies for overhead projection
4. Colored pencils

Procedures

Preparation

1. Make transparencies of Master Sheets 1.4–1.5.
2. Distribute Activity Sheets 1.2a–1.2b and ask each student to read the Activity Sheets.

Discussion

1. After the students have completed their maps, lead a discussion. Are there volcanoes on every continent? (yes) How many of the volcanoes on their map are located within the shaded area, "The Ring of Fire?" (14)
2. Show the class the transparency of Master Sheet 1.5, the "Plate Tectonics Map." With a colored marker, trace the

plate outlines. Tell students that the outer layer of the Earth is broken into a series of 16 major plates and that the colored lines indicate the boundaries between these plates.

3. Next, superimpose the transparency of Master Sheet 1.4, "Volcanoes Map," on Master Sheet 1.5, the "Plate Tectonics Map."

4. Ask students to observe the location of the volcanoes in relationship to the plates. Where do most of the volcanoes occur? They should observe that most occur near plate boundaries. Is the "Ring of Fire" located near plate boundaries?

5. Use (*poster fig. 2*) to explain that rigid plates float on top of a softer layer of rock. As the plates move, they push together, pull apart, or slide past each other. Along two plate boundaries, magma comes to the surface and volcanoes can occur.

6. Explain that there are some volcanoes that occur in the interior of plates and not at plate boundaries. They occur over "hot spots" in the plates. Scientists do not know exactly why hot spots develop, but hot spots are places in the Earth's interior from which magma rises and erupts through the plate as it moves over the hot spot. Ask students which U.S. State is composed primarily of shield volcanoes? (Hawaii)

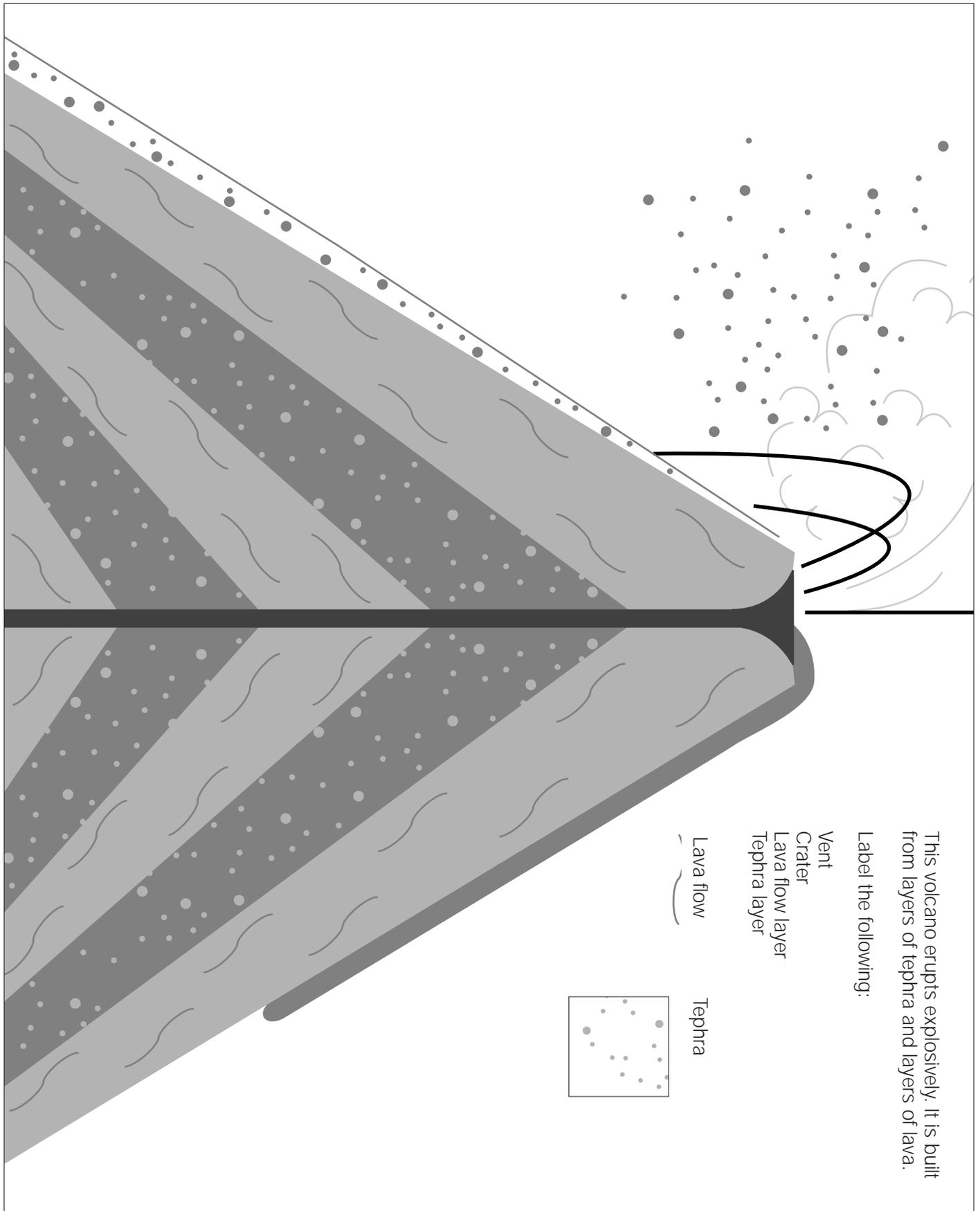
7. Is Mount St. Helens located in the "Ring of Fire"? (Yes)

This teaching packet was originally published and printed in 1997. The online edition contains full text from the original publication. Some images have been modified or added to improve the scientific visualization of information. This document has undergone official review and approval for publications established by the National Mapping Division, U.S. Geological Survey.

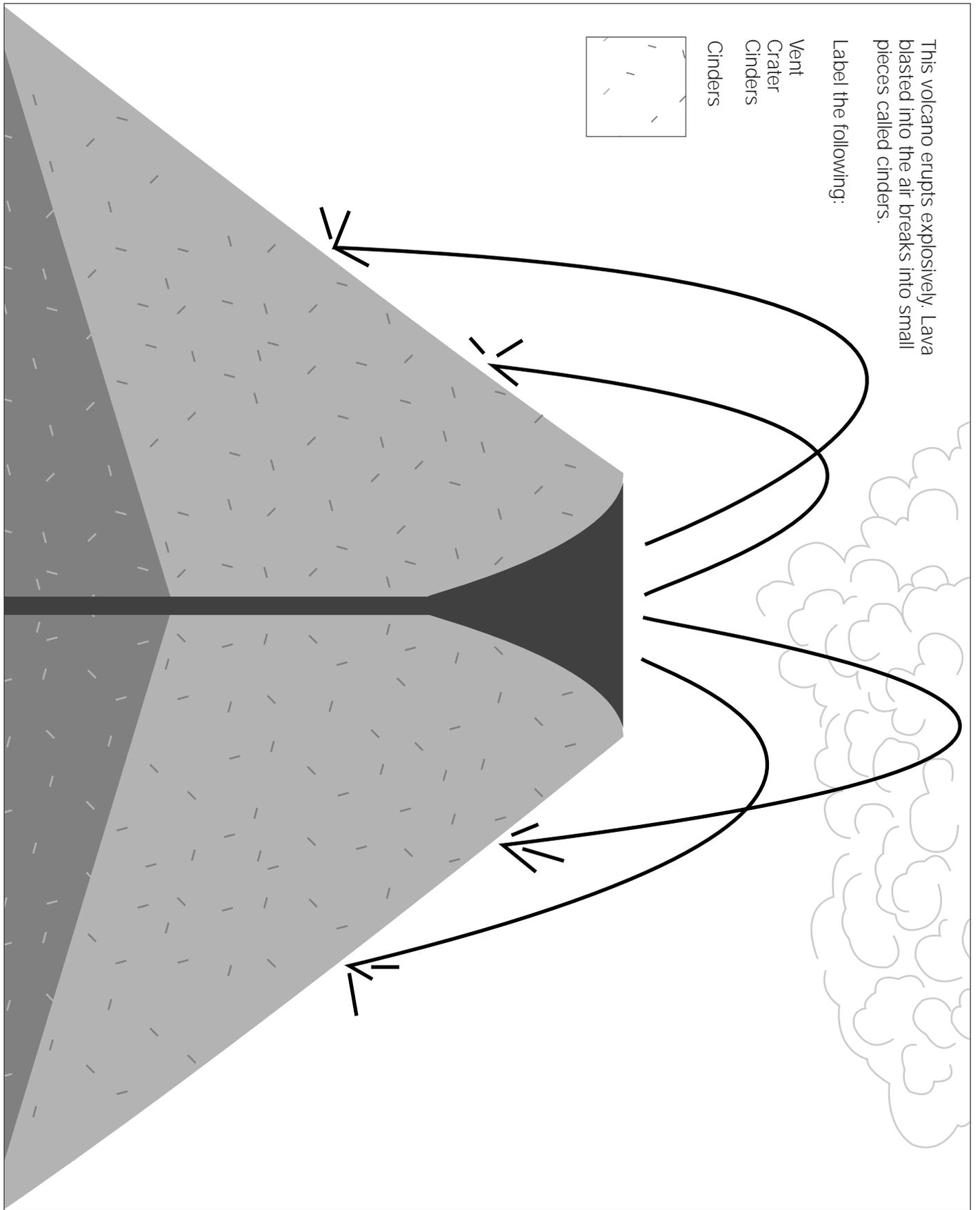
Activity Sheet 2 Answers

1. Yes
2. 66.6%
3. 33.3%
4. 14 stratovolcanoes; 1 shield; 8 cindercone
5. Stratovolcano
6. Answers will vary

Master Sheet 1.1



Master Sheet 1.2



Master Sheet 1.3

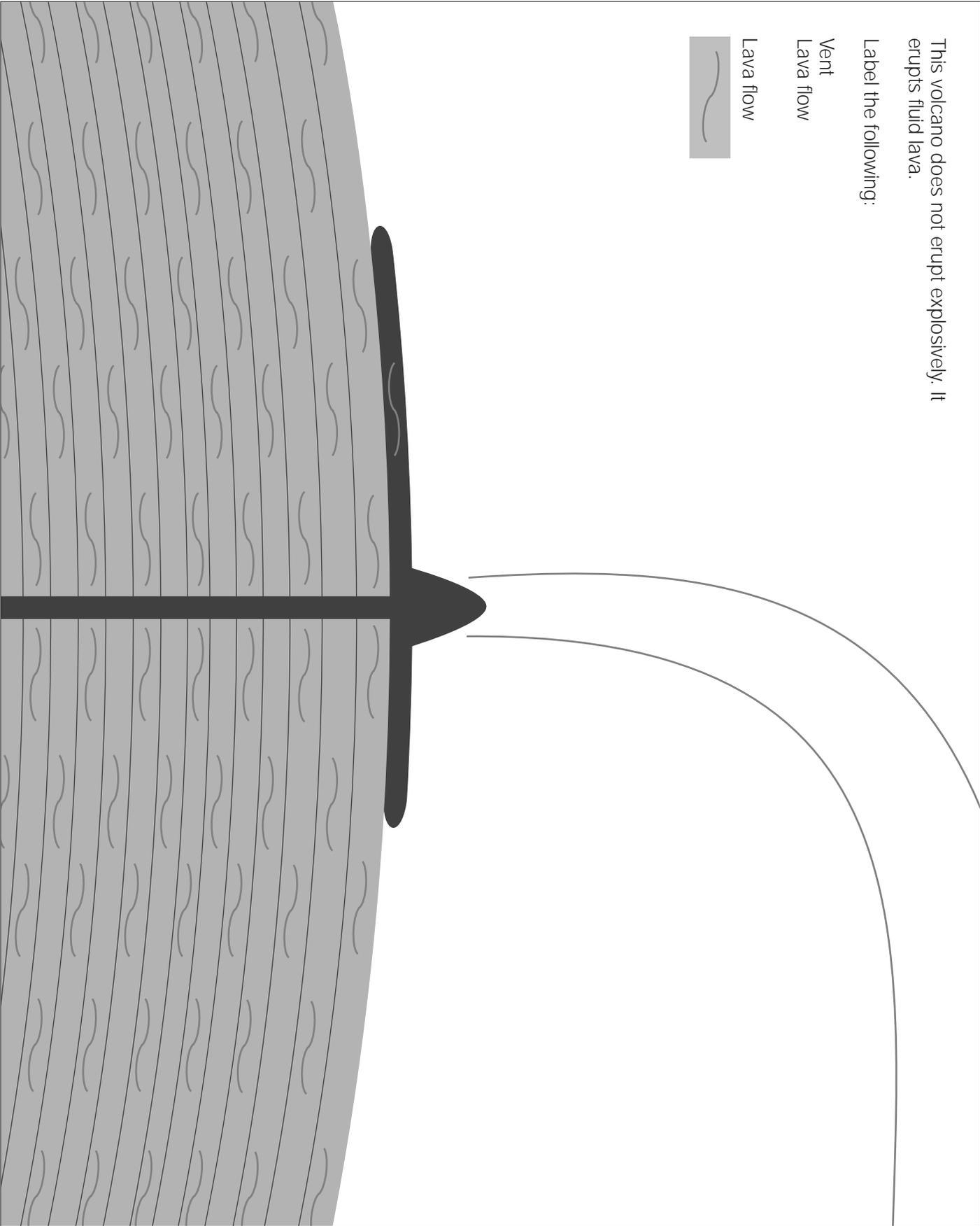
This volcano does not erupt explosively. It erupts fluid lava.

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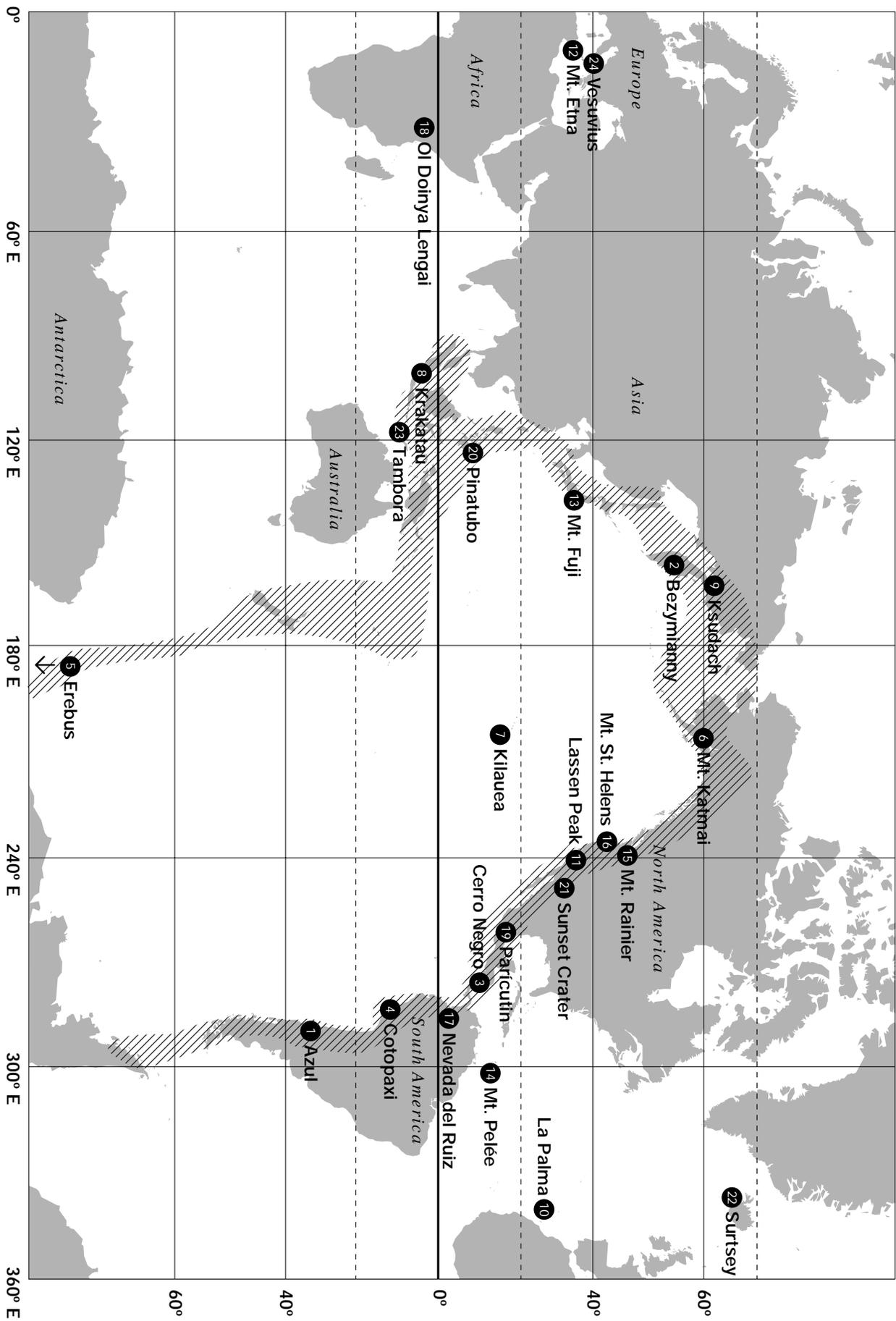
Vent

Lava flow

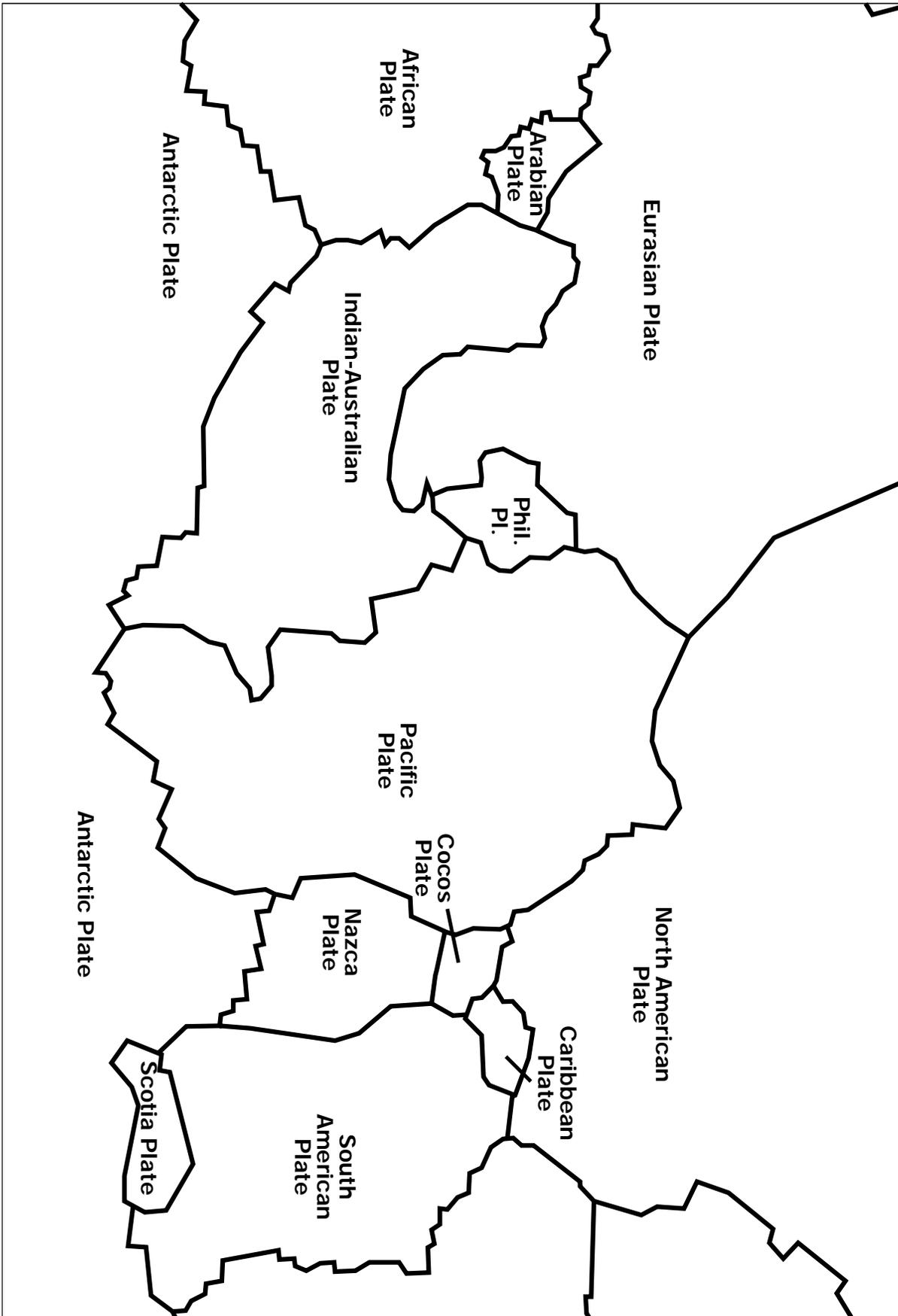
Lava flow



Master Sheet 1.4



Master Sheet 1.5



VOLCANOES!

Activity Sheet 1.2a The "Ring of Fire"

There are more than 1,500 **active volcanoes** in the world. An active volcano is one that has erupted at least once in the past 10,000 years and is likely to erupt again. Because most of the Earth's volcanoes are hidden under the oceans, people have not been able to witness their eruptions. Every

year, about 50-60 volcanoes erupt on land where people might be able to see them. Scientists estimate that there are about 200 volcanic eruptions under the oceans.

The shaded area on your map is called the "Ring of Fire." Do the exercise below and you will discover why.

What to do

Locate and label each of the volcanoes listed on the blank map. Use a different colored marker for **stratovolcano**, **shield**, and **cinder cone** volcanoes.

1. Are most of the volcanoes located in the Ring of Fire?

2. What percentage of the volcanoes are located in the Ring of Fire? To find out use the following formula:

$$\frac{\text{\# in shaded area}}{\text{total \#}} \times 100 = \text{_____\% of volcanoes in the Ring of Fire}$$

3. What percentage of the volcanoes are located outside of the Ring of Fire? To find out use the following formula:

$$\frac{\text{\# not in shaded area}}{\text{total \#}} \times 100 = \text{_____\% outside of volcanoes in the Ring of Fire}$$

4. Types of volcanoes in the Ring of Fire

of stratovolcanoes

of shield volcanoes

of cinder cones

5. What type of volcano is most common in the Ring of Fire?

6. How many of the volcanoes listed have erupted since you were born?

This is a list of some active, or recently active, volcanoes.

Name	Type	Last Erupted
1 Azul	Stratovolcano	1967
2 Bezymianmy	Stratovolcano	1993
3 Cerro Negro	Cinder cone	1971
4 Cotopaxi	Stratovolcano	1942
5 Erebus	Stratovolcano	1980
6 Katmai	Stratovolcano	1912
7 Kilauea	Shield	1995
8 Krakatau	Stratovolcano	1894
9 Ksudach	Shield	1907
10 La Palma	Stratovolcano	1954
11 Lassen Peak	Stratovolcano	1914
12 Mt. Etna	Shield	1993
13 Mt. Fuji	Stratovolcano	1709
14 Mt. Pelée	Stratovolcano	1932
15 Mt. Rainier	Stratovolcano	1894
16 Mount St. Helens	Stratovolcano	1986
17 Nevada del Ruiz	Stratovolcano	1991
18 Ol Doiño Lengai	Stratovolcano	1993
19 Parícutin	Cinder cone	1952
20 Pinatubo	Stratovolcano	1992
21 Sunset Crater	Cinder cone	1065
22 Surtsey	Shield	1967
23 Tambora	Stratovolcano	1967
24 Vesuvius	Stratovolcano	1944

VOLCANOES!

Activity Sheet 1.2b The "Ring of Fire"

